A Knowledge-based Approach for the Analysis of Maritime Traffic

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Abstract. The maritime environment is diverse, open but partly ruled, and covers a large spectrum of ships from small sailing boats to tankers which generally exhibit type-related behaviours. Several real-time positioning systems have recently emerged for keeping track of ships movements. However data provided by these reporting systems are underutilized to help operators in charge of maritime safety and security. This paper introduces an information system relying on user-defined navigation rules and an inference engine to analyse maritime traffic and to report abnormalities and suspicious behaviours to the operators. The proposed approach improves the existing ones by combining a spatial-temporal database and a rule-based inference engine.

Keywords: Information and Database Systems, Spatio-Temporal Databases, Inference Engine, Maritime Traffic

1 Introduction

The maritime environment is a place where human activities (sailing, fishing, goods transportation...) continuously evolve and where traffic increases regularly [13]. This leads to navigation difficulties and risks in coastal and crowded environment. The disasters and damages caused by sea collisions can pose serious threats to the environment and human lives. As such, the maritime surveillance has become a major concern and aims to prevent disasters and damages. The maritime surveillance centres also strive to preclude illegal immigration, drug smuggling, and terrorism.

Within the last decade, researches have tried to address the need to improve the maritime surveillance operations through computer-based information systems. To be effective, a maritime surveillance system must be capable of detecting abnormal ships behaviours in real time and enhancing situation awareness.

Several studies have investigated different strategies to offer systems able to understand maritime situations. Some studies have proposed spatial ontology to describe maritime traffic and identify dangerous and suspicious behaviours [10], [14]; some have focussed on anomaly detection through supervised statistical analysis [3], [2], [7], [8]; some others have worked on behavioural typology and rule-based reasoning [5], [4], [11]; and yet others have proposed interactive systems [9].

Nonetheless, understanding maritime situations and vessels intentions requires a thorough spatial-temporal analysis of ships localisations. Although geospatial situational contexts have been described in previous researches, the integration of geospatial analysis within the operational surveillance system still requires improvements.

The information system (based on the Drools inference engine) presented in this paper aims to address this improvement. It presents an approach to implement a maritime surveillance decision support system. The application combines a bottom-up and a top-down approach. The bottom-up method refers to the analysis of static and dynamic geo-maritime information. The top-down method refers to the possible reconfiguration of the knowledge based system by the surveillance operator.

2 Rule-based reasoning to support maritime decision system

The design of a highly flexible surveillance system, where, ideally, the surveillance logic could be fully re-configured by a surveillance operator requires a different approach than conventional location-based information systems.

When using traditional imperative programming language such as Java, C++ or Python, changing the business logic of an application requires a two-step process. First, a domain expert, often a non-technical person, adjusts or amends the requirements. Second, a computer programmer encodes those requirements within the existing business logic. This two-steps process is pernicious. First, the logic is hidden within the code, incapacitating the expert to verify whether his requirements have been properly understood. Second, the frequent additions or modifications of requirements may result in the production of so-called spaghetti code [6].

Rule engines such as DROOLS (JBOSS), JRules BRMS (IBM), Haley BRMS (Oracle), can help to overcome such a situation by keeping the business logic isolated within production rules. This removes the need for a computer programmer to assist the expert in encoding his knowledge.

Also, Rule-based reasoning appears as particularly well suited for developing expert systems [12]. An expert system may be defined as a computer program able to reason over the knowledge of some domain expert in order to assist in the decision making process [1].

3 Architecture

A computing architecture has been designed for the real-time monitoring and analysis of the maritime traffic and the automated detection of abnormal ships behaviours. The platform developed is a Java-based software with a multi-tiers architecture, and is organised through a distributed data and processing model (Figure 1).

The persistence layer relies on a spatial-temporal relational database (Postgis). Several schemas have been defined: one for the user-defined geographic information (e.g. a line ships should not cross), one for each official electronic nautical chart (ENC) used by the system (Fig. 1, geographic data), one for the short-term positioning data (Fig. 1, real-time data), and one for the historical positioning data (Fig. 1, historical data). Finally editable rules defining maritime events to be detected are packaged and stored as files.

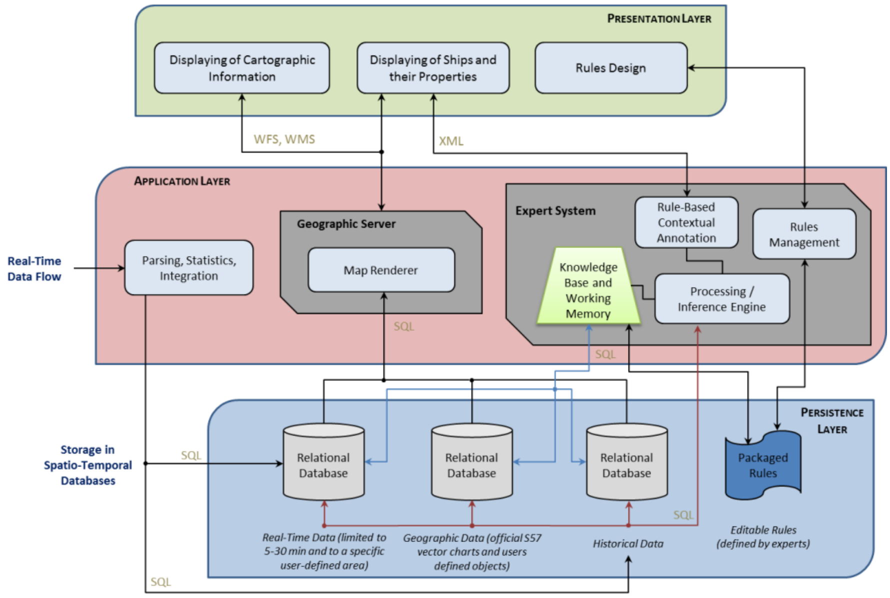

Fig. 1. Architecture

The application layer comprises three different middleware. The first middleware includes two parsers. One is dedicated to the integration of positioning data coming from the AIS, and one is devoted to the integration of the S-57 ENCs. The second middleware uses Geoserver to exchange data between the databases and the end-user (presentation layer). The third middleware encloses a Drools-based expert system.

The rule-based system is composed of three main components: a working memory filled with facts, a knowledge base filled with rules, and a rule engine matching facts with rules conditions, a process known as pattern-matching. The approach is said to be “Data Driven”, as the rules evaluation is triggered by the injection of data from the database into the working memory [1].

The rule-based contextual annotation and associated XML-based exchange language aim to provide meta information for the presentation layer. For instance, a ship detected in a restricted area will be notified with an XML element containing the ship id, the rule(s) that triggered the notification, and the associated parameters.

The graphic user interface (GUI) displays on a single interface all the data presently visualized on many different monitors [9]. The GUI is implemented (by Mines-Telecom Institut) so as to be operated with a touch table (Diamond Touch). Thence, behavioural surveillance rules can be edited directly on the visualization interface using analogical gestures.

4 System Overview

From a user perspective (top-down approach), the surveillance operator defines (Fig. 2.a) rules using specific gesture on the touch table. Then, the rules are compiled and inserted (Fig. 2.b) into a knowledge base, which produces a Rete graph for Drools.

From a data flow perspective (bottom-up approach), the positioning data received are parsed and stored in the positioning database (Fig. 2.1). Data are retrieved from the spatial-temporal database upon regular basis and inserted into the working memory (Fig. 2.2, 2.3). A pattern matching is performed between the facts and rules, using the previously generated Rete graph (Fig. 2.4, 2.5). The activated rules are placed into an agenda. Finally, a conflict resolution strategy is adopted by the rule engine to choose which rule to execute first (Fig. 2.6).

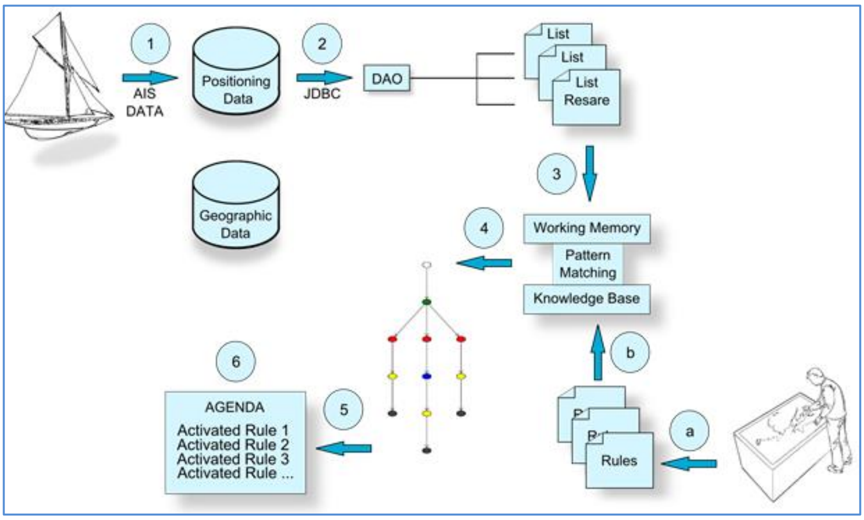

Fig. 2. Main processes involved in the system

Two approaches have been successfully implemented and tested to “spatialize” our expert system. The first approach relies on Java Topology Suite library (JTS). When evaluated by the inference engine, rules “call” JTS spatial functions and operators. The second approach consists in calling spatial SQL procedures which are executed remotely inside PostGIS. In both approaches, the call is made from inside a rule.

5 Conclusion

This paper has presented a maritime surveillance decision support system. This system relies on the analysis of dynamic and static geo-maritime information using reconfigurable rules. The rules are used to encapsulate knowledge about the situation awareness. This knowledge can either come from a thorough analysis of maritime data (bottom-up approach), or from the surveillance expert (top-down approach).

Our system improves other existing rules-based system in the domain of maritime surveillance by defining spatial rules. A computing architecture has been designed for the real-time monitoring and analysis of maritime traffic with an original combination of spatial-temporal databases and an expert system.

Following the preliminary results, further work shall address the integration of this decision support system into an operational context. As a result, the reliability of the platform could be truly evaluated.

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